Implementation of Voyage Assistant Module in Mobile Navigation System for Inland Waters

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ABSTRACT: Route monitoring is one of the most important functions in modern navigation systems. In case of marine merchant ship's it usually part of IMO-standardized solutions like ECDIS or INS. In inland waters Inland ECDIS is implemented. There is however large group of ships which do not have to follow standardized solution, like recreational ships. The skippers of these boats more and more often are using mobile devices. The paper presents considerations on implementation of voyage assistant module in mobile navigation system in inland waters. Main problems are defined solutions for them are proposed. In general proposed approach is based on mobile cartography like in car navigation and derives also from water navigation systems. The verification research are described and commented.

1 INTRODUCTION

The purpose of any navigation system on board is to assist the navigator in the process of safety navigation. Thus, from the very beginning, navigation systems provide various information supporting the officer on watch in many ways. The scope of this assistance is however different and it depends mostly on the purpose of the system. The most popular in merchant shipping are information systems like ECDIS (Electronic Chart Display and Information System), however more and more attention is laid on the possibilities of decision support, instead of only providing information. This is particularly important for recreational user, which as no-professionals requires more support from navigational systems.

A great example here is rapidly growing branch of touristic shipping in inland waters, which are generally easier accessible for recreational users. They require a system which will lead them from point to point and warn them in case of danger. The key functionality here is voyage assistance, understood as a set of functions aiming at supporting the user in navigation along the planned route. The functionality is met in many navigational systems including car navigation. The research presented in this paper aimed at providing voyage assistance functionality for touristic users on inland waters.

Inland shipping is a branch of transportation which has common issues with both – marine and car navigation. The voyage is usually planned along rivers like on the roads, but the navigation process is carried out on water.

Thus the new system has been developed dedicated for recreational users of inland waters. It is called MOBINAV and it was developed under the R&D project carried out in Marine Technology Ltd, financed by Polish National Centre for Research and Development (NCBiR). It focused on development of mobile solution dedicated for this specific group of users. Various aspects of the system were undertaken in the project, including voyage planning

(Kazimierski i in., 2015). In this research the focus is laid on assisting the user in following planned route.

The paper first undertakes the issue of route assistance in existing navigational systems, presenting the most popular approaches. Then the basics of MOBINAV system are given, including the concept of voyage assistant. The assumptions of this module implementation are presented in the next chapter, describing main challenges. Finally the implementation and its verification are described. The paper is wrapped up with the summary and conclusion.

2   VOYAGE ASSISTANT EXAMPLES

Some kind of voyage assistance is included in any navigational systems. If fact, simple presentation of own ship position on the chart may be considered as voyage assistance. For the years however more sophisticated methods have been developed. This chapter includes short review of the most popular approaches to this problem.

2.1   *IMO ECDIS and INS*

Basic IMO approved system for route management is Electronic Chart and Display System. ECDIS according to IMO is a navigation information system which displays selected information from a system of electronic navigational chart (SENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring, and if required display additional navigation-related information (IMO, 2006). The function of voyage assistant is reduced here to route monitoring. Parameters like DTW (Distance to waypoint), ETA (Estimated Time of Arrival) or XTE (cross-track error) are calculated in real-time and suitable alarms can be raised. Additionally Safety Depth Contour is displayed (Kazimierski and Wawrzyniak, 2013). The same functions are also required in Integrated Navigation System defined by IMO in (IMO, 2007). Route monitoring is one of key issues and it makes use of sensor information about own ship to inform user about navigational situation.

2.2   *InlandECDIS and RIS*

At the beginning of 21st century the concept of River Information Services (RIS) arose and since then it has been rapidly developed. One of the key issues was to find appropriate charting system for ensuring safety of navigation. It was decided to implement and expand ECDIS concept. Thus Inland ECDIS system was defined, based on ECDIS. The functional assumptions were basically the same. Some additional issues like dynamical presentation of water level were implemented. However in the aspect of route monitoring the scope is the same. It can be thus said that Inland ECDIS system provides also route monitoring in real time with some basic visual and audible alarms. (Stateczny, 2011)

It should be also said that InlandECDIS, as a standardized system is too expensive and overloaded for recreational users, which are looking for other, usually mobile solutions.

RIS itself however is a wider concept. The scope of services provided in the vision is very wide and it includes also so called navigation assistance as one of the possible services. This service assumes that the maneuver for the vessel will be recommended by shore side. This is usually a hot topic for discussion between navigators and that is probably why the service is usually not implemented in RIS Centres.

2.3   *Navigational Decision Support System*

The fact that IMO defined requirements for ECDIS and INS, does not mean that scientific and industrial society stopped providing solutions for more sophisticated systems for voyage assistance. An interesting example is Navigational Decision Support System (NDSS), which aims at dynamical adjustment of recommended route, taking into account possible solutions of collision situation around own ship. An example might be here NAVDEC, presented in (Pietrzykowski et. all, 2012). Route is monitored as in ECDIS, but additionally navigator is advised with recommended maneuver to be undertaken for safe passage of the vessels. After the recommended maneuver, optimized trajectory for going back to previously planned route is calculated and displayed to the user. It can be thus seen that NDSS significantly develops route monitoring system given in ECDIS.

2.4   *E-Navigation*

Interesting concept aiming at introducing more ICT (Information and Communication Technologies) to sea is IMO-led e-navigation. It is defined as *the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment* (IMO, 2008).

The initial wide concept has been narrowed to the proposal of five solutions focusing mainly of integrating and presentation of navigational data (Weintrit, 2013). Although voyage assistant is not directly mentioned in the documents, it can be expected that improved proposals of solutions taking into account this issue will appear.

One of the interesting approaches is maritime Cloud, which assumes wide exchange of data between ships and shore services. In main proposal topical services have been defined and vessels could make use of them by downloading and integrating information. Thus routes can be provided from shore side and information about planned routes can be exchanged. Additional features have to be designed for ECDIS to support these issues.

From the point of view of this paper, interesting are also attempt of introducing in e-navigation concept also so called non-solas ships. Recreational users, for which MOBINAV is dedicated, are included in this group. . Detailed description of navigation and

communication systems based on cloud computing for non-solas ships can be found for example in (An, 2016).

2.5 *Car navigation*

Nowadays, car navigation has become a standard feature of newly purchased cars. It is available in fixed version in car interior or in portable version. Car navigation is designed to carry the user from point A to point B without detracting the focus from the direction of travel and the environment.

Graphic display is the main element of car navigation, which displays the map, interface and additional information about the route. Digital map contains geographic information about roads, buildings, point of interest, etc. but also the attribute information describing them (Obradovic, 2006). Information can also be supplemented by the Internet connection where the driver receives traffic information.

The interaction with the user is also carried out by audio, where voice messages about route are played. The devices are equipped with a GNSS (Global Navigation Satellite Systems) sensor so information about the location of the vehicle on the map, route planning and navigational guidance is provided (Eskandarian, 2012).

3 MOBILE NAVIGATION SYSTEM FOR INLAND WATERS

Users of inland waterways can be divided into two main groups. First, there are professional users, navigating cargo or passenger barges. These ships have to be equipped according to conventions and the crew is well educated and prepared for professional navigation of ship. These users usually use standardized InlandECDIS as navigation system. The second group includes so called recreational users, which are using smaller boats usually form time to time and professionally performs other jobs. Touristic boats or yacht do not have to be equipped with standardized solutions. Usually there is a need for simple, but reliable mobile navigation system dedicated for these users. Such system was developed under R&D project in Maritime Technology Ltd. and called MOBINAV (MObile Inland NAVigation).

3.1 *MOBIVAV*

MOBINAV itself is a system, which is to help in navigation for touristic users of inland waters. From user's point of view it is just another application installed in mobile device. From inventors point of view the system has also second component, which is shore station managing servers with updates and other data. Main functionalities of the system may be divided into 9 groups:
- visualization of data and analysis results, according to given cartographic model;
- supporting of dedicated spatial analysis;
- navigation/voyage support funcitons;
- route management;
- supporting of POI (Points Of Interest) and own informations;
- downloading and processing of data from external sources;
- sharing of information.

Main research works in the project concerned issues with spatial data processing (mainly spatial analysis) and cartographical presentation method. Part of the task also included technological issues like sensor integration or mobile device implementation.

One of the main modules of the system is voyage assistant, which main task is to provide alerts and information about current situation, taking into account planned route. The module is focused on clear and precise information dedicated for the user at current situation. It is assumed that user is more used to car navigation than professional navigation systems like ECDIS. Therefore the module implementation uses typical mobile cartography methodology. The analysis and alerts however are dedicated for inland water solutions and not for car navigation.

3.2 *Concept of voyage assistance in MOBINAV*

Voyage assistant is an advanced analytical module, which supports interaction with user via voice and visual notices. It aims at informing user about dangers and events, while performing navigation along the route. The concept is that assistant makes calculations in the background and suitable notices are provided to the user. Assistant monitors the route and informs the user about status of the route, giving parameters to active waypoint and to the end of the route. Apart of these typical route monitoring options, a set of additional events dedicated for inland water user has been implemented.

In general, functions provided by voyage assistant can be grouped into following:
- handling of voyage assistant in general (activation, interruption and resuming);
- continuous functions – calculations made by assistant in real-time (distance to go, distance to waypoint, cross-track error, course to steer);
- event handling functions – functions provided as a response to defined events;
- advanced functions – advanced spatial analysis.

Two first two groups are typical for any route monitoring software. "Events" covers also some typical functions like waypoint handling, but the set of dedicated solutions is also included. These are for example bridge approaching or depth analysis and suitable warnings. The last group covers advanced solutions found useful by potential users. They are described more thoroughly in section 4.2.

The effort in designing voyage assistant was also laid in adjusting it to mobile device and to mobile users' needs. The assumptions of mobile navigation system led to various challenges for implementation.

3.3 Implementation Challenges

Main implementation challenges in case of mobile navigation system are driven by the characteristics of mobile devices and by the purpose of the navigational systems themselves. Two groups of challenges are considered:

- performance challenges:
    - real-time system;
    - integration of many sensors (internal and external);
    - size of data in charts;
    - frequent change of situation;
    - small device and many requirements;
- cartographic challenges:
    - small screen and many information;
    - frequently changing situation – frequent change of required information;
    - various user needs;
    - various user preferences;
    - changing scales of presentation;
    - context change of required information.

All these challenges were taken into account and mobile cartographic presentation model, as well as voyage assistant functional model were proposed as a response for them.

4 IMPLEMENTATION OF VOYAGE ASSISTANT IN MOBINAV

The implementation of voyage assistant in MOBINAV had to solve challenges given in section 3.3 and to provide functionalities described in section 3.2. At first, two models were developed as a base for test implementation – cartographic model and functional model. The first one covers the issues related to management of dynamically adaptive presentation for providing the set of information needed by the user in each time. Cartographical model supports also personalization of presentation. The second one includes selected functions for assistant to fulfill the requirements, especially dedicated spatial analysis.

It has to be emphasized that in order to support mobility of the solution, geofencing technology has been proposed. The technology usually used for marketing purposes can be as well used in navigational solutions. Detail description of proposed concept is given in (Wawrzyniak and Hyla, 2016).

4.1 Cartographic presentation model

Cartographic presentation model was based on the theory of mobile cartographic presentation in which presentation itself is defined as a set of geovisualtlization which are contextually changed in the geovisualization window. Cartographic events are defined to steer the process, which are the rules for changing the geovisualization (Gotlib, 2011). Full presentation model for the system is given in (Kazimierski, 2015).

The voyage assistant is mainly based on cartographic events. Display of a function, message, and symbol or voice information occurs when a particular spatial analyst condition has been done. In order to implement individual cartographic events, spatial analysis was designed based on chart vector data model and real-time date from positioning sensor.

In the implementation part of the voyage assistant, a graphic interface of displayed messages and symbols was designed. A number of iconographic images have been designed to convey information during the completion of the cartographic event (Fig. 1)
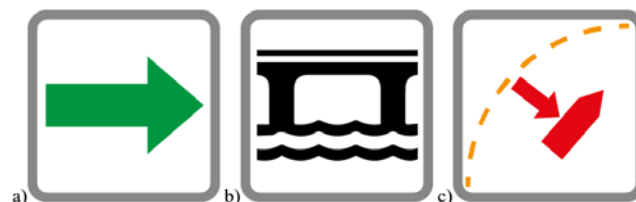

Figure 1. Exaples of message icons

The message is displayed on the user's application screen. Depending on the message, the user can:
- manual closing of the message
- automatic closing of the message - message conditions are no longer avaible,
- automatic closing after a specified time.

4.2 Functional model

The functionality of implemented voyage assistant is based on route monitoring concept known from information systems, but is significantly expanded with functions and analysis dedicated for inland shipping. On the other hand the model should not be too complicated, as it is dedicated to any standard user of the recreational boat. After the analysis of user needs and performance possibilities it was decided that voyage assistant should support 19 events presented in table 1. They have been grouped to ease the presentation of concept. Some issues dedicated for inland shipping are given already in route recommendation messages, like *after next buoy alter your course*. This kind of information is more likely in car navigation than in marine system, which confirms the thesis, that inland shipping is something between. The set of voyage alarms and warnings raised is given in the last part of the table. Although the alarms themselves are not very extraordinary and can be also met in sea navigation (except bridge alert), their implementation, based on geofencing is an example of using mobile technology for navigation system.

Some positions in the table are examples of advanced tools which are planned in the system, but which were not yet implemented in demonstrator. These are related to buoyage and fairway analysis. It is intended that the maneuvers to undertake will be also given to users in relation to the surrounding items, like "alter your course after the next buoyage". These are examples of advanced spatio-temporal analysis. Another one is analysis of the terrains available to be reached in the assumed amount of time. This analysis is also intended to be implemented in next steps.

Table 1. Voyage assistant events

Event	audio information	visual information
handling of the assistant		
navigation initialized	yes	yes
finish navigation?	no	yes
navigation stopped	yes	no
navigation resumed	yes	yes
route calculations		
distance to target	yes	no
next waypoint in …	yes	no
warning! you are too far from planned route	yes	yes
route recommendations		
proceed on course …	yes	no
follow the fairway on course	yes	yes
alter your course to port/ starboard on …	yes	yes
after passing next buoy, alter your course to …	yes	yes
you are approaching next waypoint	yes	yes
you are approaching bridge	yes	yes
destination achieved	yes	no
alarms and warnings		
low bridge ahead	yes	yes
shallow water ahead	yes	yes
you are in shallow water	yes	yes
danger object ahead	yes	yes
danger area ahead	yes	yes

4.3 Test implementation

Test implementation of voyage assistant has been provided in MOBINAV demonstrator. The demonstrator itself was prepared as universal application for Windows 10 with Microsoft Visual Studio. This approach allows preparing of one application, which can be launched in any mobile device based on Windows 10. The interface of the application can automatically change and adjust to the device.

Main functions of the demonstrator are:
- supporting of MOBINAV data model based on *gml*;
- supporting of cartographic presentation model based on *json*;
- dynamic changing of geocomposition, according to mobile cartographic presentation model;
- integration of internal and external sensors;
- voyage assistant;
- selected spatial analysis.

Test implementation in the form of demonstrator was then tested to verify system functionality in simulation and real environment. Details about testing of cartographic model were presented in (Bodus-Olkowska et. all, 2017).

5 TESTING OF VOYAGE ASSISTANT MODULE

Voyage assistant module was tested together with entire MOBINAV demonstrator. Verification tests were performed first in simulation and then in real environment. The goal of simulation test was verification of proper implementation of functions and of technical readiness of demonstrator for final testing in real environment. Final testing was focused on verifying usefulness of developed system and correctness of taken assumptions. Additionally the system, including voyage assistant was compared to InlandECDIS.

5.1 Verification in simulation

Simulation tests were performed in the dedicated testing station prepared in the project. All the signals from external devices were simulated to create environment very similar to real. Main module of station was a computer acting as a server with dedicated software for generating NMEA strings from various devices. The software allows defining of own ship maneuvers and movement parameters like speed, course, etc. as well as simulation of other information, like for example depth. The data are then transferred as NMEA strings via WLAN network to client devices, which were mobile phones with MOBINAV installed.

There are several advantages of such approach. Firstly, it is possible to verify the system simultaneously in a few devices analyzing the influence of hardware properties on the application. Secondly, it is possible to simulate any movement and any scenarios, also these, which are hard to achieve in real conditions. Furthermore, the situation can be repeated many times to find statistical response of the system.

In the aspect of voyage assistant the simulation environment was used mainly for verifying correctness of implementation, understood as complying with documentation and following earlier developed assumptions and algorithms. Other important goal was to check the integration of sensor information in system.

The results of this phase of tests allowed stating following conclusions:
- all sensors used in tests are properly integrated and displayed in system;
- modifications in waypoint management functionality were proposed;
- proposals of voyage assistant interface was proposed.

The demonstrator was corrected according to simulation tests results prior to verification in real environment.

5.2 Verification in real environment

Verification in real environment was the final phase of testing of demonstrator and its modules. It was conducted first on the small recreational boat of type Cortina 480 (length 4,80 m) and then additionally on HYDROGRAF XXI, which is a floating hydrographical laboratory in Maritime University of Szczecin (length 9 m). Such approach allowed testing of the system in typical recreational boat as well as in boat equipped with advanced systems. Additionally comparison with InlandECDIS installed in Hydrograf

XXI was allowed. The surveys were conducted in inland waters around Szczecin, Poland.

This stage of tests was performed in the form of acceptance tests - functioning of all components was checked. Additionally the usefulness of each module was judged. This stage was the only one in which the analysis based on geofencing could have been checked. In the aspect of voyage assistant, all its functionalities have been tested and verified. Example picture presenting one of the messages raised during testing is given in figure 2.

Verification in real environment led to following conclusions on voyage assistant module:
- in general voyage assistant was verified positively;
- in real navigation voyage assistant is key component and its implementation significantly increased value of the system for user;
- the set of messages is properly chosen – no lacking messages were indicated;
- cartographic model and the interface of voyage assistant is intuitive and user-friendly;
- using of geofencing is a helpful idea, however key calculations should not rely on it due to relatively poor accuracy;
- major variations in performance capabilities of different devices were noticed, influencing functioning of assistant module;
- the information messages should not be too long as real situation is often changing dynamically;
- energy problems were not an issue during tests.

Figure 2. Exaple message of voyage assistant

It can be said that voyage assistant was found as a useful tool and that the concept of mixing car navigation technology into water navigation system was a good idea. Additionally comparing to Inland

ECDIS showed that MOBINAV data model is more complicated, but also provides more information. Voyage assistant module was noticed as key advantage of MOBINAV over Inland ECDIS.

6 SUMMARY

The paper presented research on implementing voyage assistant module in mobile navigation system for inland waters. The review of approaches to this problem in existing navigation systems was followed by the proposal for mobile inland navigation system MOBINAV. MOBINAV was shortly described, but the impact was laid on voyage assistant module.

The idea of implementing route monitoring functions in this system was to join good practices from professional systems like InlandECDIS and from car navigation, which is commonly used mobile approach. Thus a solution dedicated to mobile devices was created which derived also from maritime and inland experiences. Typical monitoring functions were expanded and new possibilities dedicated for inland water users were added.

Development of voyage assistant module for the system required designing of functional model and cartographic presentation model. Intense works was undertaken especially to provide suitable mobile cartographic model, as the mobility of the device was key issue here. It forced including context changes of the presentation itself.

The verification of proposed solution performed in simulation and real environment has proven that the assumptions taken were right. The functionality and quality of the presentation was satisfactory. It was noticed that proposed solution is scalable and can be used in any kind of navigational system.

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